Catawba-Wateree Hydroelectric Relicensing Process
Draft
Water Quality Resource Committee Report

1.0 Purpose

This Resource Committee (RC) Report is the bridge by which Catawba-Wateree (C-W) Relicensing study results are delivered to the relicensing stakeholder teams (State Relicensing Teams and Advisory Groups) for their education, use, and consideration as they negotiate to develop the Agreement-In-Principle (AIP). It has been prepared by the Catawba-Wateree Relicensing Water Quality Resource Committee and supplements the detailed study and technical reports available at http://www.dukepower.com/community/lakes/cw/library/plans/quality.asp. [Technical reports and calibration reports (i.e., companion documents to the WQ RC report) were not available for the June draft RC report submittal but will be provided for the final RC report submittal in September 2005. Therefore, the findings presented in this version of the RC report are preliminary conclusions from Duke Power consultants and do not represent a collective peer review process involving all members of the RC. However, it is anticipated that these findings will be further reviewed and validated by all members of the RC after development of the technical reports and prior to release of the final RC report.]

Please note that this document is a resource assessment, not a regulatory certification. The purpose of this report is to: 1) consolidate and summarize preliminary key study findings of the water quality related studies (i.e., Water Quality Studies 01 and 02) including those based on the historical and recent water sampling data, the reservoir water quality model (CE-Qual-W2) and the regulated river water quality model (RMS); 2) merge the preliminary findings of the technical studies into a coordinated resource assessment; and 3) provide the Resource Committee's assessment of potential resource protection, mitigation and enhancement opportunities supported by study findings. Due to the preliminary nature of the information contained in this report, the North Carolina Division of Water Quality (NCDWQ) and South Carolina Department of Health and Environmental Control (SCDHEC) may be unable to concur with, or even consider, preliminary findings prior to unrestricted review and acceptance of data, models, model results, technical report, calibration report and any other information that may be necessary to demonstrate compliance with water quality standards. The water quality certifications that must be issued by each state are strict regulatory processes that will be conducted after the license application is filed.

1.1 Water Quality Resource Committee Members

The following individuals are members of the Water Quality RC Team

- Donna Lisenby-Catawba Riverkeeper
- Scott T. Fletcher-Devine Tarbell and Associates-RC Coordinator
- Jon C. Knight-Devine Tarbell and Associates-Study Lead
- Bill Foris-Duke Power
- David Buetow-Mecklenburg County Department of Environmental Protection
- Darlene Kucken-North Carolina Division of Water Quality
- Steve Reed-North Carolina Division of Water Resources
- Chris Goudreau-North Carolina Wildlife Resources Commission
- Todd Ewing-North Carolina Wildlife Resources Commission
- Jack Huss-Area 2 NC Soil and Water Conservation Service
- Wade Cantrell-South Carolina Department of Health and Environmental Control
- Vivianne Vejdani-South Carolina Department of Health and Environmental Control
- Larry Turner-South Carolina Department of Health and Environmental Control
- Hank McKellar- South Carolina Department of Natural Resources

- Ben West-US Environmental Protection Agency

2.0 Contents

This Water Quality Resource Committee Report includes:

- For each study within this Resource Committee's overview:
    - A brief summary of the study's purpose(s)
    - A brief summary of the methods/procedure used for the study
    - A brief summary of the Key Findings for each study
- At the Resource Committee level, a coordinated resource assessment of any potential Protection or Mitigation needs or Enhancement opportunities that are supported by the study findings.

3.0 Study Summary – Purpose, Methods and Findings

3.1 Study Purpose

The water quality purpose and objectives are divided into two primary areas: 1). The collection of data and subsequent empirical data analysis of new and existing data primarily in evaluation of Section 401 (Clean Water Act) requirements, and 2). The development of appropriate computer models to evaluate various potential impacts on water quality due to proposed future operations scenarios. It is important to note that the models used in these analyses are based on a particular set of assumptions, and that the WQ RC has not participated in the selection of these assumptions. The purpose and objectives of the Water Quality Study are as follows:

1. Identify the current status of water quality for each project development:
    a. Reservoirs
        i. Characterize the distribution and concentrations of major chemical constituents within the reservoirs under a variety of project operations.
        ii. Identify the influence of project operations on reservoir stratification
    b. Tailrace and Riverine Sections
        i. Characterize the water quality of the hydro release
        ii. Characterize the downstream temperature and dissolved oxygen concentrations (and transport of other water quality constituents) under a variety of Project operations (flow)
        iii. Establish the extent of project influence on the downstream water quality
        iv. Determine the mixing characteristics and identify the current status of hydro operations on tailwater and downstream water quality (lateral and dynamics of longitudinal variability)
    c. Bypassed Reaches
        i. Characterize the existing water quality in applicable river bypassed reaches
2. Identify and evaluate the impact of feasible alternative operating, engineering, or policy scenarios on water quality
    a. Reservoirs
        i. Identify the influence of reservoir inflow and meteorological extremes on reservoir water quality.
        ii. Evaluate the impact of reservoir water level fluctuation and outflow patterns on reservoir water quality
        iii. Establish the extent of project influence on reservoir water quality

b. Tailrace and Riverine Sections
   i. Evaluate the hydro operations and engineering alternatives to improve downstream water quality
   ii. Establish the extent of project influence on the downstream water quality
   iii. Provide recommendations for long-term, continuous monitoring of downstream water quality
c. Bypassed Reaches
   i. Evaluate altered flow patterns on reservoir or tailrace water quality

3.2 Study Methodology

The following information is a summary of the detailed water quality plan prepared for the Project. The detailed study plan can be reviewed at the Duke Power relicensing website mentioned above.

Routine Data Collection
Water quality has been monitored on the Catawba River reservoirs for approximately 45 years. One task was to consolidate the numerous water quality databases available for the Catawba River reservoirs and tributaries. Only pre-2004 data from state certified laboratories were considered for consolidation into a comprehensive database. Presently, water quality data have been requested or obtained from Duke Power, the NCDWQ, the SCDHEC, the United States Geological Survey (USGS), and the Mecklenburg County LUESA. Data have been regularly collected on the Catawba River reservoirs and tributaries by Duke Power since 1959; by NCDWQ since 1968 (lake data since 1981); by SCDHEC since 1958; by USGS in 1993 and 1994; and by Mecklenburg County since 1988. All available data has been consolidated.

The 2004 data collection program consists of routine collections from the immediate tailwaters, reservoirs, assorted tributaries and by-passed reaches, and downstream areas. The routine data collection consists of continuous monitoring of temperature, dissolved oxygen, conductivity, and water level in the tailraces; continuous monitoring of water level and temperature at selected locations; monthly physical/chemistry sampling within the reservoirs and selected tributaries; and, bi-weekly sampling of chemical parameters in the tailraces.

Non-Routine Data Collection
The non-routine portions of the water quality studies were designed to evaluate both the immediate tailrace and the downstream water quality responses (lateral and longitudinal mixing) to the full range of operating capability of the hydro. The studies were conducted during the summer months when dissolved oxygen concentrations in the reservoirs are typically at minimum levels. Non-routine tests have been conducted for Rhodhiss, Oxford, Lookout, and Wateree hydros. Prior to 2004, non-routine tests were conducted at the Wylie hydro. These flow tests were designed to support both empirical data analysis and provide calibration data for the RMS computer model. The downstream temperature, dissolved oxygen, conductivity, and water level are continuously recorded during periods of low flows and generation flows. The long-term monitoring of temperature, dissolved oxygen, and conductivity in the tailrace of the hydro forms the basis for the timing of these experimental hydro evaluations. Calibrated Hydrolabs and level loggers (i.e., water quality testing equipment) have been placed in the tailrace and downstream reaches though out the duration of the hydro tests. The placement of the Hydrolabs have been designed to evaluate both the lateral and longitudinal mixing patterns of the river. In addition,

placement of the instruments also takes into account the morphometric characteristics of the tailrace, e.g. large pools that could be re-regulation areas for flow.

Computer Modeling

Upon calibration, the CE-QUAL-W2 reservoir water quality models will receive as input data collected from watershed inflows which coupled with hydro operations is used to predict water quality within the reservoir(s) and the water released from the hydro. These simulations will use various flow scenarios provided by other studies, e.g. CHEOPS operations model, Instream Flow Incremental Methodology (IFIM). In addition, the reservoir models are being used in conjunction with the RMS riverine water quality models by taking the output (hydro release) from the reservoir model as inputs to the riverine model. Upon calibration of the RMS riverine models, the models will be used to evaluate water quality in the downstream reaches below the Bridgewater, Oxford, Wylie, and Wateree hydro plants utilizing various flow scenarios provided by other studies, e.g. CHEOPS, IFIM, etc. Water quality and quantity released from an upstream reservoir directly into the downstream reservoir is being used as inputs for the downstream reservoir. In this fashion, reservoir operational criteria or proposed criteria (flows, lake level, etc.) scenarios are evaluated on the downstream reservoir and subsequent water quality. Also, results from the riverine model are used as inputs (flow and water quality) to the downstream reservoir. By using these models (riverine and reservoir) together, upstream events and/or changes are evaluated on the downstream riverine or reservoir systems.

Individual models (both CE-QUAL-W2 and RMS) have been prepared for each of the developments including reservoir and riverine sections. Linking CE-QUAL-W2 models is a difficult task. The linkages require extremely accurate model calibrations of all reservoirs. Upstream errors would be transferred downstream in a linked system. Calibrating individual models is more accurate since the upstream boundary conditions are derived from measured sampling data rather than model output. Success of this modeling project is more likely achieved by breaking system segments into reservoir and riverine models with a plan to soft link data between reservoir and riverine models which is the current modeling approach.

3.3 Key Findings and Results

3.3.1 Applicable Findings to all Catawba –Wateree Projects

3.3.1.1 Applicability of the Clean Water Act Section 401 Water Quality Certification

The Clean Water Act (CWA) was enacted to protect the environmental quality of the U.S. waterways. It provides the statutory basis for states to implement water quality standards, pollution discharge permitting, and other means to protect water resources. Section 401 of the CWA (water quality certification) applies to hydropower project relicensing. It requires an applicant to obtain certification from the state water quality agency that hydropower project discharges will be in compliance with the water quality standards. Standards are designed to limit the impacts to water quality and protect beneficial uses of the waterway, such as water supply, aquatic resources, and recreation. Duke Power expects to file for its 401 Water Quality Certification in both states within 60 days after FERC announces that Duke Power's application for new license is ready for environmental review. The anticipated date for the submittal of the North Carolina and South Carolina Section 401 applications is June 2007 which is approximately 12 months after the submittal of the Final FERC license application.

In reviewing the proposed activity for state certification, it is the responsibility of the state 401 agencies to review applications for such and determine if there is a reasonable assurance that the project will be in compliance with all applicable state regulations. If the project is in compliance with all applicable state regulations, the state agency will certify the project and FERC can issue the license (as long as state water quality conditions are incorporated into the license). However, if the state agency does not have a reasonable assurance that the project will be in compliance will all applicable state regulations, project certification will be denied and FERC may not issue a license when a state denies 401 Water Quality Certification. Specific 401 issues as they relate to North and South Carolina are as follows:

North Carolina

Duke Power must comply with all applicable regulations of Section 401 of the CWA through state regulation 15A NCAC 02H.0501. Certification is required when there is a discharge into navigable waters. The certificate is verification by NC that the project will not degrade state waters or violate water quality standards. Several specific NC Section 401 issues include, but are not limited to, water temperature, dissolved oxygen, compliance monitoring, aquatic life, and minimum flows.

South Carolina

Duke Power must comply with all applicable regulations of the South Carolina State 401 Water Quality Certification (Regulation 61-101) pursuant to Section 401 of the Clean Water Act, 33 U.S.C. Section 1341, the requirements of Regulation 61-68 Water Classifications and Standards and Regulation 61-69 Classified Waters. Water quality issues of interest in the Catawba-Wateree project include, but are not limited to, phosphorous, dissolved oxygen, pH, temperature, fecal coliform, turbidity, and aquatic life.

3.3.1.2 General Process Influencing Water Quality of Reservoirs and the Riverine Reaches

The following section provides an educational overview on the basic water quality processes and their relationship to the Catawba-Wateree River and reservoir system. Specific detail on these concepts is provided in summary form in Section 3.3.2 of this RC report. The references and background associated with these details is provided in a companion technical report.

Duke Power's system of dams and reservoirs on the Catawba-Wateree controls the rate of water movement through the reservoir system. The timing of reservoir releases changes the residence time of water in the reservoir and the pattern of downstream flows. Residence time influences several water quality constituents directly and many more indirectly. Temperature, dissolved oxygen (DO), and the production of algae are affected directly by residence time. The timing and degree of thermal stratification (the separation or layering of colder and warmer waters within the reservoirs) is also directly related to residence time. DO concentrations in reservoirs are related to thermal stratification, oxygen demand (biological, chemical, and sediment), and the timing and depth of water releases. Residence time and the availability of nutrients and light affect the dynamics of algal growth. In turn, algae play a critical role in the DO balance of the system. In the context of reservoir operations, residence time, thermal stratification, DO depletion, and algal growth are key water quality processes. They reflect overall water quality conditions, eutrophication, and the ability of the reservoir to assimilate waste.

Other water quality conditions are also important to the reservoir system. Very low DO concentrations (referred to as anoxic conditions) can mobilize or dissolve metals, sulfides, and ammonia contained in bottom sediments. Nutrient loadings (nitrogen and phosphorus) from the watershed play an important role in the growth of algae in the reservoirs. Erosion, sedimentation, and turbidity are affected by impoundments and project operations, such as release flows and drawdowns. Reservoir releases can increase downstream erosion and sedimentation, which can affect algae and other aquatic life. Other water quality issues are largely unaffected by reservoir operations. Examples include bacterial contamination and contamination of sediments by polychlorinated biphenyls (PCBs).

3.3.1.3 Project Influence on Water Quality

Project influence is considered as an alteration in water quality as a result of impoundment, storage, and subsequent release of water. Important reservoir processes that are potentially affected by reservoir operations include residence time, thermal stratification, DO depletion, algal growth, and sediment transport and anoxic products. The following sections examine these processes with respect to existing conditions and potential impacts from changes in reservoir operations.

Residence Time

By their name and function, reservoirs are constructed to retain flowing water. One of the primary mechanisms by which reservoirs and reservoir operations affect water quality is the residence time. Residence time is used to characterize the amount of time that is available for physical, chemical, and biological processes to occur within a reservoir. For example, a residence time of 300 days would suggest a reservoir with sufficient time for thermal stratification, algal growth, reduced DO, and a variety of related biological and chemical processes to show an effect. In contrast, a residence time of 10 days would suggest substantial water movement and little time for these processes to make a substantial change in water quality.

Thermal Stratification

Temperature is important because of its effect on aquatic life and reservoir mixing (Churchill and Nicholas 1967 and TVA 1978). The maximum summer temperature of a reservoir and the amount of cold water available influence the type of fish community that can exist, as well as the species and distribution of other biota. Temperature affects physical properties, such as DO, and influences the chemical and biological reactions that take place in aquatic systems (Wetzel 2001).

Water temperature in reservoirs varies depending on the season and the amount and temperature of water entering each reservoir. During cooler weather, temperatures are uniform from the surface to the bottom. As the days get longer and hotter, the temperature of the surface water rises. Since warm water is less dense than cold water, it floats on top of the cooler water. This density difference inhibits mixing, resulting in thermal stratification which separates water into horizontal layers by temperature.

In Catawba-Wateree reservoirs, thermal layering or stratification typically starts between April and July as the sun warms the surface layers. Stratification typically persists into late fall or early winter, when surface waters cool and the reservoir turns over or mixes from top to bottom. Surface waters in some reservoirs may approach or exceed 30°C in late summer. Releases of water from dams are typically through low-level turbine intakes, resulting in cooler tailwater temperatures and a reduction in the volume of cold water in the reservoir as the summer progresses.

The low-level release results in colder tailwater temperatures and earlier fall turnover as the warmer surface waters replace the released water. As the cooler water is depleted, the temperature of the release water in the tailwater may rise, depending on the year, reservoir, or operations. Tailwater temperatures below reservoirs can fluctuate during the summer stratification period as turbines are cycled on and off, periodically releasing cold reservoir water that is subsequently warmed as it moves downstream. During dry years, stratification is typically stronger and persists longer into fall. During wet years, stratification is weaker and breaks down earlier in the season. Late in the season, as air temperatures cool, inflow to the reservoirs is often cooler than surface waters. Under these circumstances, inflows enter the reservoirs at mid-depth, creating an interflow. These relatively short-lived events can give rise to atypical DO and water chemistry profiles.

Shorter days and cooler air temperatures during fall cool the surface, gradually allowing it to mix with more and more of the water column. By late October to November, the mixing is complete, resulting in similar temperatures and DO concentrations from surface to bottom.

DO Depletion
The importance of DO in rivers and reservoirs is twofold. First, DO is critical for the survival of aquatic organisms. Second, the amount of DO in the water affects many of the chemical reactions that take place in rivers and reservoirs. DO is added to reservoirs from the atmosphere and from oxygenated inflows. In addition, during daylight hours, algae produce oxygen in the surface waters where there is sufficient light. DO is removed from reservoirs by decaying organic materials, plant and animal respiration, and sediments. Oxygen is also lost when inflowing point sources of pollution (primarily from municipal wastewater and industrial discharges) and non-point sources (primarily from agriculture and stormwater runoff) enter the reservoirs and decay, using up DO in the process.

Once thermal stratification is established in a reservoir, DO in deeper water cannot be replenished from the air or from contact with the oxygen-rich surface water. Over time, DO is reduced as organic material sinks to the bottom and decays, potentially resulting in low DO concentrations in the lower layers. The bottom sediments also use oxygen in the decay of organic matter. As oxygen is depleted, iron, manganese, ammonia, and sulfide can be released from the sediments. The amount of nitrogen, phosphorus, and other nutrients entering the water through soil erosion, sewage treatment plant discharges, polluted runoff, and natural sources affects this process. The more nutrients increase, the more algae grow; the more algae grow, the more decaying organic matter is present and the lower the DO concentrations in the deep portions of the reservoir.

The release of water from the lower levels of a reservoir can result in low concentrations of DO in the tailwaters and downstream. This condition decreases aquatic habitat and stresses aquatic life.

Algal Growth
Algal growth in reservoirs is important because of its potential impact on recreation, water supply, and DO. As organic matter from dead and dying algae settles, it decomposes and consumes oxygen in the water column. Sediments in reservoirs with high algal growth accumulate rapidly; these sediments are thick and nutrient-rich. They consume large amounts of

oxygen from the overlying waters as they decompose. A total loss of oxygen in the lower layers of reservoirs with high algal growth is common (Cooke et al. 1993).

Although reservoir operations have little influence on nutrient inflows from the watershed, the way nutrients cycle in the reservoirs may change in response to operational changes. In addition, algal growth in the reservoirs may change in response to changes in the timing of water movement through the system. Internal nutrient cycling, residence time of water in impoundments, and the timing of reservoir releases are all processes controlled in part by reservoir operations. Each of these factors influences algal growth in the system.

Sediment Transport and Anoxic Products

Contaminated sediments are a water quality concern in some reservoirs and tailwaters. Contaminants such as mercury, cesium, PCBs, and pesticides are often associated with sediments. Changes in reservoir operations under consideration are unlikely to disturb reservoir sediments and mobilize contaminants.

Other materials found in sediments (e.g., iron, manganese, sulfides, and ammonia) may be formed and mobilized in the lower waters of the reservoir when oxygen concentrations are low. These potential pollutants can adversely affect water supplies, recreation, and aquatic life. Changing reservoir elevations or reservoir residence times could affect the duration or severity of low DO conditions that, in turn, introduce iron, manganese, sulfides, and ammonia into the water column. Because the occurrence of these compounds is so closely tied with low DO concentrations, DO is used as a surrogate for these parameters in the impact assessment.

3.3.2 Findings to Specific Catawba –Wateree Projects

<u>BRIDGEWATER DEVELOPMENT</u>

Lake James

<u>Findings (General Overview)</u>

- Lake James is the second largest storage reservoir on the Catawba System. It is formed by three earth embankment dams, one across the main stem of the Catawba River, one across Paddy Creek, and one across the Linville River. A diverting canal connects the reservoir formed by the Catawba dam with the reservoir formed by the other two dams.
- With its long retention time, the majority of Lake James has excellent water quality.
- Duke Power operates the Bridgewater hydro for peaking energy or downstream water demands within the guidelines of a seasonal lake level target.
- There is currently no supplemental aeration capability being utilized at Bridgewater

<u>Findings (Existing Conditions)</u>

- Lake James stores the cold, well oxygenated winter inflows. The winter water temperatures and the level of dissolved oxygen are dependent upon the severity of the winter. [**data analysis and modeling**]
- As the Bridgewater turbines release the water from deeper in the reservoir from the Paddy Creek and Linville side of Lake James downstream, temperatures deeper in the reservoir in the forebay gradually increase while dissolved oxygen progressively decreases. [**data analysis and modeling**]

- Conversely, the turbines cannot access the deep, cold water stored in the reservoir formed by the Catawba dam due to the bathymetric restriction imposed by the connecting canal. Therefore, the Catawba side of Lake James exhibits very strong thermal stratification. [**data analysis and modeling**]
- Lake James receives relatively high concentrations of nutrients and organic matter from the North Fork Catawba and Catawba River inflows, and low nutrients and organics from the Linville River. [**data analysis and modeling**]
- Algae are significant near the headwaters of the Catawba arm where nutrients are high, but algal activity is low near the dams due to low nutrient levels. [**modeling**]
- The organic material, both received from the watershed and from the algae produced in the lake, contribute to the lower dissolved oxygen concentrations in the deeper layers, this is most pronounced in the upper Catawba basin. [**modeling**]
- Lake James acts as a major trap for phosphorus, due to sorption onto inorganic sediments that settle out of the water column. [**data analysis and modeling**]

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Bridgewater Bypassed Reaches

<u>Findings (Existing Conditions)</u>

- There are two bypassed reaches below Lake James and these include the Catawba Bypassed Reach and the Paddy Creek Bypassed Reach. Both bypassed reaches flow into Muddy Creek before it enters the Catawba River downstream of the Bridgewater hydro. These areas are not currently meeting state water quality standards for aquatic uses (i.e., flows).
- Overall, the water quality of the bypassed reaches is good. Concentrations of most constituents are typical of streams draining the upper Piedmont, i.e. near saturated dissolved oxygen, low dissolved solids, metal concentrations at or near the detection limit, and low nutrient levels. [**data analysis]**
- The water quality in the Catawba bypassed reach, downstream of the confluence with Muddy Creek, exhibited elevated levels of suspended sediment and total phosphorus originating from Muddy Creek. Increased concentrations of major dissolved solids in the lower end of this reach suggested ground water contributions to bypassed flow. **[data analysis]**

Bridgewater Tailwater

<u>Findings (Existing Conditions)</u>

- Coldwater releases from Bridgewater hydro enable the establishment of a downstream trout fishery. During most summer periods, the water temperatures released from Bridgewater hydro are less than the 20ºC standard established for trout waters. However, summers with higher flows deplete the cold water reserve in Lake James at a faster rate, with late fall water temperatures exceeding the 20ºC standard for trout by a few degrees in the tailwaters. [**data analysis and modeling**]
- The higher flows discharged from the Bridgewater turbines, the farther downstream the cool water is able to persist in the trout section. When there is no generation at Bridgewater, leakage water temperatures warm rapidly due to shallow depths and warm inflow from the Catawba River bypassed reach due to contribution of Muddy Creek flow. [**data analysis and modeling**]

- On the average, during May – November, 29% of the hourly average dissolved oxygen concentrations released from Bridgewater hydro are lower than the current state standard of 4 mg/l instantaneous 42% are lower than the 5 mg/l trout standard). [**data analysis**]
- On the average, during May – November, 43% of the daily average dissolved oxygen concentrations released from Bridgewater hydro are lower than the current state standard of 5 mg/l daily average 54% are lower than the 6 mg/l trout standard). [**data analysis**]
- Year to year variation in the dissolved oxygen concentrations of the turbine releases were a function of:
    - Lake James watershed loading in the winter – spring period (high flows, lower DO) [**data analysis**]
    - Colder winters enabled more dissolved oxygen at the onset of Lake James spring stratification [**data analysis]**
    - Warmer autumn weather delayed the winter mixing events in Lake James contributing to progressively lower dissolved oxygen concentrations [**data analysis]**
- During low flows and no generation, DO increases rapidly in downstream reaches. Conversely, low DO (worst case) from Bridgewater release is pushed farther downstream during high turbine flow. However, even at high turbine flow, DO aerates to 5 mg/L to about 7 miles below the dam. [**data analysis and modeling**]

RHODHISS DEVELOPMENT

Lake Rhodhiss

Findings (General Overview)

- Lake Rhodhiss has a moderately short retention time. With minimum storage capability, Rhodhiss Reservoir is dynamic and at most times, inflow driven.
- Overall- water quality in Lake Rhodhiss is nutrient rich and is classified by NCDWQ as impaired.
- Duke Power operates the Rhodhiss hydro for peaking energy or to maintain target lake levels.
- Currently, Unit 2 has stay vein aeration capability, the performance of aeration is being evaluated.

Findings (Existing Conditions)

- Phosphorus contributions due to point source and non-point discharges are not fully processed before being exported via dam discharge. [**modeling**]
- Phosphorus patterns are very dynamic, and are driven by loadings that get diluted and redistributed by intermittent reservoir flow. [**modeling**]
- Algal activity occurs at the surface in the downstream third of the reservoir where residence times are longer. (Add sentence of the major algal types and how the dominant species is a blue-green and is not represented by Chlorophyll a-provided in technical report). [**modeling**]
- Low DO occurs due to sediment oxygen demand along the bottom where residence times are longer, and in the middle reservoir depths due to algal respiration. [**modeling**]
- Low flow (i.e., long retention time) periods, coupled with higher, undiluted nutrient concentrations, exhibit the lowest DO levels within the reservoir and, subsequently, released from the reservoir. [**modeling**]

Rhodhiss Tailrace

Findings (Existing Conditions)

- On the average, during May – November, 13% of the hourly average dissolved oxygen concentrations released from Rhodhiss hydro are lower than the current state standard of 4 mg/l instantaneous [**data analysis**]
- On the average, during May – November, 37% of the daily average dissolved oxygen concentrations released from Bridgewater hydro are lower than the current state standard of 5 mg/l daily average [**data analysis**]
- Actual five year (1997-2000) average nutrient Bridgewater Releases Compared to Rhodhiss Releases: [**data analysis**]
  - Phosphorus – increase from 10 ug/l to 46 ug/l
  - Dissolved Organics – increase from 1.3 mg/l to 1.9 mg/l
  - Particulate Organics – increase from 0.4 mg/l to 2.7 mg/l.

OXFORD DEVELOPMENT

Lake Hickory

Findings (General Overview)

- Lake Hickory has a moderate retention time. Most of the flow entering Lake Hickory comes from the Rhodhiss hydro and during thermal stratification passes through the lake as an interflow between the surface layer and the bottom water.
- Overall-according to NCDWQ water quality is poor due to nutrient rich levels.
- Duke Power operates the Oxford hydro for peaking energy or to maintain target lake levels.
- Both Units have turbine venting capability and have been used intermittently in the past. The performance is being evaluated.

Findings (Existing Conditions)

- Lake Hickory receives elevated levels of phosphorus from several primary sources: Rhodhiss releases and five point sources discharge directly to the lake. The highest levels of phosphorus from Rhodhiss occur during the months of January through March, increasing the phosphorus levels in Hickory just before the spring growing season. [**data analysis and modeling**]
- Lake Hickory traps a significant amount of phosphorus. [**data analysis and modeling**].
- Water quality parameters will be evaluated with projected sedimentation rates (i.e., loss of storage capacity) within the reservoir and downstream projects [**data analysis and modeling**]

Oxford Tailwater

Findings (Existing Conditions)

- On the average, during May – November, __ % of the hourly average dissolved oxygen concentrations released from Oxford hydro are lower than the current state standard of 4 mg/l instantaneous [**data analysis**]

- On the average, during May – November, __ % of the daily average dissolved oxygen concentrations released from Oxford hydro are lower than the current state standard of 5 mg/l daily average [**data analysis**]
- Actual five year (1997-2000) average nutrient Rhodhiss Releases Compared to Oxford Releases: [**data analysis**]
  - Phosphorus – decrease from 46 ug/l to 22 ug/l
  - Dissolved Organics – no change, 1.9 mg/l at both hydros
  - Particulate Organics – decrease from 2.7 mg/l to 1.1 mg/l.
- Temperature and DO are very dynamic in the 3-mile tailwater between Oxford Dam and headwater of Lookout Shoals Reservoir.
  - Temperature and DO both increase rapidly at all locations in the tailwater during mid-day in summer if there is no generation. This occurs due to shallow depths and extensive aquatic vegetation. [**data analysis and modeling**]
  - During generation, fluctuations in temperature and DO are dampened. [**data analysis and modeling**]

LOOKOUT SHOALS DEVELOPMENT

Lookout Shoals Reservoir

Findings (General Overview)

- With its short retention time, Lookout Shoals Reservoir is largely inflow driven, so release temperatures and water quality reflect inflow conditions
- Overall-according to NCDWQ, water quality is poor due to nutrient levels.
- Duke Power operates the Lookout Shoals hydro for peaking energy or to maintain target lake levels.
- There is currently no supplemental aeration capability being utilized at Lookout Shoals

Findings (Existing Conditions)

- Stratification is weak and intermittent. Longer residence times occur at the surface and near the bottom in the downstream third of the reservoir. [**data analysis and modeling**]
- Low DO occurs due to sediment oxygen demand in deep forebay areas where residence time is longer. [**modeling**]
- Algal levels increase at the surface in the downstream third of the reservoir where residence times are longer. [**modeling**]

Lookout Shoals Tailwater

Findings (Existing Conditions)

- On the average, during May – November, __ % of the hourly average dissolved oxygen concentrations released from Lookout Shoals hydro are lower than the current state standard of 4 mg/l instantaneous [**data analysis**]
- On the average, during May – November, __ % of the daily average dissolved oxygen concentrations released from Lookout Shoals hydro are lower than the current state standard of 5 mg/l daily average [**data analysis**]
- Actual five year (1997-2000) average nutrient Oxford Releases Compared to Lookout Shoals Releases: [**data analysis**]
  - Phosphorus – no change, 22 ug/l at both hydros

- Dissolved Organics – no change, 1.9 mg/l at both hydros
- Particulate Organics – no change, 1.1 mg/l at both hydros

<u>COWANS FORD DEVELOPMENT</u>

Lake Norman

<u>Findings (General Overview)</u>

- Lake Norman is the largest storage reservoir on the Catawba System.
- With its long retention time, Lake Norman has excellent water quality.
- Duke Power operates the Cowans Ford hydro for peaking energy or downstream water demands within the guidelines of a seasonal lake level target.
- There is currently no supplemental aeration capability being utilized at Cowans Ford

<u>Findings (Existing Conditions)</u>

- Lake Norman stores the cold, well oxygenated winter inflows. Duke Power manages this cold water resource for cooling water for Marshall Steam Station and McGuire Nuclear Station [**data analysis and modeling**]
- The submerged skimmer weir immediately upstream of Cowans Ford hydro prevents the turbines from accessing the deep, cold water stored in the lake. [**data analysis and modeling**]
- Thermal stratification is both a function of the bathymetric restriction imposed by the skimmer weir and the use of the cold water by Marshall and McGuire steam stations. [**data analysis and modeling**]
- The primary source of nutrients and organic matter is from the Lookout Shoals releases. [**data analysis and modeling**]
- Algae are significant near the mid to upper lake where nutrients are highest; as nutrients are depleted, algal activity decreases progressively towards Cowans Ford dam [**data analysis and modeling**]
- The organic material, both received from Lookout Shoals and from the algae produced in the lake, contribute to the lower dissolved oxygen concentrations in the deeper layers. [**modeling**]
- Lake Norman acts as a major trap for phosphorus, due to sorption onto inorganic sediments that settle out of the water column [**data analysis and modeling**]

Cowans Ford Tailwater

<u>Findings (Existing Conditions)</u>

- On the average, during May – November, __ % of the hourly average dissolved oxygen concentrations released from Cowans Ford hydro are lower than the current state standard of 4 mg/l instantaneous [**data analysis**]
- On the average, during May – November, __ % of the daily average dissolved oxygen concentrations released from Cowans Ford hydro are lower than the current state standard of 5 mg/l daily average [**data analysis**]
- Actual five year (1997-2000) average nutrient Lookout Shoals Releases Compared to Cowans Ford Releases: [**data analysis**]
    - Phosphorus –decrease, 22 ug/l to 11 ug/l
    - Dissolved Organics – decrease, 1,9 mg/l to 1.7 mg/l
    - Particulate Organics – decrease, 1.1 mg/l to 0.6 mg/l.

MOUNTAIN ISLAND DEVELOPMENT

Mountain Island Reservoir

Findings (General Overview)

- With its short retention time, Mountain Island Reservoir is largely driven by the inflows of Cowans Ford, so release temperatures and water quality reflect these inflow conditions.
- Overall-according to NCDWQ, water quality is good.
- Duke Power operates the Mountain Island hydro for peaking energy or to maintain target lake levels.
- There is currently no supplemental aeration capability being utilized at Mountain Island

Findings (Existing Conditions)

- Thermal loading from Riverbend Steam Station, coupled with high, periodic flows from Cowans Ford cause weak and intermittent stratification. [**data analysis and modeling**]

Mountain Island Tailwater

Findings (Existing Conditions)

- On the average, during May – November, __ % of the hourly average dissolved oxygen concentrations released from Mountain Island hydro are lower than the current state standard of 4 mg/l instantaneous [**data analysis**]
- On the average, during May – November, __ % of the daily average dissolved oxygen concentrations released from Mountain Island hydro are lower than the current state standard of 5 mg/l daily average [**data analysis**]
- Actual five year (1997-2000) average nutrient Cowans Ford Releases Compared to Mountain Island Releases: [**data analysis**]
  - Phosphorus – no change, 11 ug/l at both hydros
  - Dissolved Organics – no change, 1.7 mg/l at both hydros
  - Particulate Organics – increase, 0.6 mg/l. to 1.1 mg/l

WYLIE DEVELOPMENT

Lake Wylie

Findings (General Overview)

- Lake Wylie has a moderate retention time. Most of the flow entering Lake Wylie comes from the Mountain Island hydro and South Fork River.
- Duke Power operates the Wylie hydro for peaking energy, maintenance of target lake levels, and downstream water use. In addition, Allen Steam Station withdraws cooling water from the Catawba River arm (downstream from Mountain Island hydro) and discharges the heated water to the South Fork arm.
- Turbine venting tests have been performed on Units 2 and 3 with good results. Unit 1 has minimal aeration capacity and Unit 4 has no turbine venting capability.

Findings (Existing Conditions)

- The water quality in the discharges from Mountain Island is very good, and the nutrients in the South Fork Catawba are elevated primarily due to point sources from WWTPs. [**data analysis]**
- Overall-according to NCDWQ, water quality is considered impaired in the North Carolina portion of the reservoir due to nutrient levels. South Carolina does not currently consider the reservoir impaired for nutrients. (Station CW-027 Impaired for Recreation due to Fecal Coliform; Station CW-197 Impaired for Aquatic Life and Copper). North Carolina and South Carolina have different water quality assessment methodologies, monitoring requirements and criteria.
- Heated, low nutrient water withdrawn by Allen Steam Station 'floats' on the surface of the South Fork Catawba arm of the reservoir and usually causes the high nutrients from the South Fork Catawba to enter the remainder of Wylie Reservoir as an interflow. The interflow of South Fork water limits the availability of nutrients to algae growing in the surface layers. [**data analysis and modeling**]
- Wylie Reservoir also receives elevated levels of phosphorus from Crowders Creek. [**data analysis]**
- Due to the highly variable water withdrawal zones of Wylie hydro, coupled with the influence of Allen Steam Station, water currents in Wylie are dynamic and thermal stratification is weak and transient. [**data analysis and modeling**]

Wylie Tailwater

Findings (Existing Conditions)

- On the average, during May – November, __ % of the hourly average dissolved oxygen concentrations released from Wylie hydro are lower than the current state standard of 4 mg/l instantaneous [**data analysis**]
- On the average, during May – November, __ % of the daily average dissolved oxygen concentrations released from Wylie hydro are lower than the current state standard of 5 mg/l daily average [**data analysis**]
- Actual five year (1997-2000) average nutrient Mountain Island Releases Compared to Wylie Releases: [**data analysis**]
    - Phosphorus – increase from 11 ug/l to 33 ug/l
    - Dissolved Organics – increase, 1.7 mg/l to 2.7 mg/l
    - Particulate Organics – increase from 1.1 mg/l to 1.6 mg/l.
- The 30-mile river reach from Lake Wylie to Fishing Creek Reservoir is one of the longest free flowing reaches in the study area. Downstream from Lake Wylie, DO is primarily controlled by Wylie generation; progressively downstream, aquatic plant growths dominate river DO (need technical detail/information-standards, river mileage extent etc.). Preliminary hydro tests indicate that aeration of Wylie's turbine flow only extends DO enhancements to Sugar Creek (approximately 10 miles) [**data analysis**]

FISHING CREEK DEVELOPMENT

Fishing Creek Reservoir

Findings (General Overview)

- Fishing Creek reservoir has a very short retention time. With minimum storage capability, Fishing Creek Reservoir is dynamic and at most times, inflow driven. Stratification is weak. [**data analysis and modeling**]
- Duke Power operates the Fishing Creek hydro for peaking energy or to maintain target lake levels.
- Units 1, 2, and 3 have minimal aeration capacity. Currently, Units 4 and 5 have no turbine venting aeration capability.

Findings (Existing Conditions)

- SC classifies Station CW-225 impaired for Aquatic Life due to Copper and Station CW-0578 impaired for Aquatic Life due to Total Phosphorus.
- Stratification is weak to moderate but stable for the most part. Longer residence times occur at the surface and near the bottom in the downstream half of the reservoir. Longest residence times occur in the downstream third of the reservoir near the bottom. [**data analysis and modeling**]
- Fishing Creek Reservoir receives high concentrations of nutrients and organic matter from the watershed downstream from Wylie Dam as well as some elevated phosphorus concentrations in the discharges from Wylie [**data analysis and modeling**]
- Total phosphorus in the inflows to Fishing Creek is 3 to 4 times greater than the SCDHEC water quality standard and 6 to 7 times greater than the TP level in the Wylie releases. Much of this increase is related to municipal wastewater discharges into Sugar Creek which enters the Catawba River upstream of Fishing Creek Reservoir. In addition, a USC (2003) assessment of TP in the watershed between Wylie and the inflow to Fishing Creek indicated that additional nonpoint sources were needed to balance the simulated phosphorus budgets for the lower reservoirs (Fishing Creek Reservoir and Lake Wateree) [**data analysis]**
- Organic matter entering Fishing Creek is almost ___ times greater than that discharged from Wylie Reservoir. [**data analysis]**
- The nutrients and organic loads are attributed to Municipal and Industrial wastewater discharges as well as nonpoint sources entering the watershed between Wylie and the inflow to Fishing Creek Reservoir. [**data analysis]**
- These pollutant loads cause high algae concentrations, producing even more organic matter, and low DO in Fishing Creek Reservoir. [**data analysis and modeling**]
- Fishing Creek Lake traps about 15% of the TP entering the reservoir through sedimentation and biological processing . [**data analysis and modeling**]
- Algae concentrations in the lake sometimes exceed 100 ugChl*a*/L, which is greater than the SC DHEC standard of 40 ugChl*a*/L. [**data analysis and modeling**]
- BOD_5 values in the river upstream from Fishing Creek reservoir are 2-3 times normal levels ([**data analysis**].
- The short residence time in Fishing Creek Lake prevents wide ranging and frequent episodes of low DO at the surface of the lake. DO concentrations can be less than 5 mg/L at the surface only ___ % of the reservoir. Concentrations of DO less than ___ mg/L periodically can occur at the surface of the lake in some parts of the reservoir [**data analysis and modeling**]
- First steps are being taken to reduce TP in the watershed. CMUD has agreed to:
    - A permitted TP load from the McAlpine Creek WWTP that is about 50% less (on a 12-month rolling average basis) than current actual TP daily loads and about zero % less during peak "mass cap" months (which can occur consecutively as long as

the 12-month target is met). Considering this WWTP currently has an average discharge of about 42 MGD instead of the permitted discharge level of 64 MGD and if they achieve the target TP concentration level of 1 mg/L in their discharge, the immediate TP reduction would be ~ 67 % from the current TP load.

- Reduce current combined TP loads from McAlpine, Irvin, and Sugar Creek WWTP's by ~ 43 to 57 % and less than zero % (i.e., allow more than current daily average loads) during peak "mass cap" months. (note: the two values given for % reductions depend on the value of the "current" load from the Sugar Creek WWTP, whether the baseline is prior to June 2001 or starting in June 2001—TP was significantly reduced in their discharges in June 2001)
- These TP limits are based on achieving a limit of 1 mgTP/L in the permitted discharges from these CMUD WWTPs.
- Other actions are being studied to optimize reduction of TP discharges
- SCDHEC is requiring Mun&Ind WWTPs in SC to limit the TP concentrations in their discharges to 1 mg/L. In addition, a TMDL for TP for Fishing Creek and Fishing Creek lakes is being developed by SCDHEC. The 1 mg/l was determined appropriate a number of years ago based on the permitted flows at that time. However, the 1 mg/l limit was also converted to a mass loading and for a number of dischargers that mass limit is now the limiting factor on the permit. Some permittees have increased flow but the mass limit has remained the same even though the concentration limit might stay at 1 mg/l to allow operating and compliance flexibility, the mass limit is limiting. Basically, mass is limiting and the SCDHEC are not allowing unlimited flow increases as long as a concentration limit of 1 mg/l is met.

Fishing Creek Tailrace

Findings (Existing Conditions)

- On the average, during May – November, 13% of the hourly average dissolved oxygen concentrations released from Fishing Creek hydro are lower than the current state standard of 4 mg/l instantaneous [**data analysis**]
- On the average, during May – November, 37% of the daily average dissolved oxygen concentrations released from Fishing Creek hydro are lower than the current state standard of 5 mg/l daily average [**data analysis**]
- Actual five year (1997-2000) average nutrient Wylie Releases Compared to Fishing Creek Releases: [**data analysis**]
  - Phosphorus – increase from 33 ug/l to 221 ug/l
  - Dissolved Organics – increase from 2.7 mg/l to 5.9mg/l
  - Particulate Organics – increase from 1.6 mg/l to 9.3 mg/l.
- These increases are attributed largely to point source discharges and non-point source runoff between Lake Wylie and Fishing Creek Reservoir.

DEARBORN / GREAT FALLS DEVELOPMENT

Great Falls Reservoir

Findings (General Overview)

- SCDHEC has no long-term monitoring sites and has not assessed water quality in Great Falls Reservoir (SCDHEC to check).
- Duke Power operates the Dearborn hydro, and, to a lesser extent, Great Falls hydro for peaking energy. These units are operated only when Fishing Creek hydro operates since the Great Falls Reservoir has very limited storage.
- There is currently no supplemental aeration capability being utilized at Dearborn/Great Falls

Findings (Existing Conditions)

- Short retention times (less than one day) result in the water quality essentially mimicking the water quality released from Fishing Creek reservoir.
- Fishing Creek (River) proportionately dilutes the concentrations of the chemical constituents released from Fishing Creek reservoir.

Dearborn / Great Falls Tailrace and Bypassed Reach

Findings (Existing Conditions)

- On the average, during May – November, 13% of the hourly average dissolved oxygen concentrations released from Dearborn hydro are lower than the current state standard of 4 mg/l instantaneous [**data analysis**]
- On the average, during May – November, 37 % of the daily average dissolved oxygen concentrations released from Dearborn hydro are lower than the current state standard of 5 mg/l daily average [**data analysis**]
- Actual five year (1997-2000) average nutrient Wylie Releases Compared to Fishing Creek Releases: [**data analysis**]
  - Phosphorus – ? from 221 ug/l to __ ug/l
  - Dissolved Organics ? from 5.9 ug/l to __ ug/l
  - Particulate Organics – ? from 9.3 ug/l to __ ug/l.

CEDAR CREEK / ROCKY CREEK DEVELOPMENT

Cedar Creek Reservoir

Findings (General Overview)

- SCDHEC lists Cedar Creek Reservoir as impaired due to high total phosphorus, total nitrogen, chlorophyll a, and turbidity and low DO. Station CW-175 is listed as Impaired for Aquatic Life due to DO, Total Phosphorus, Turbidity and Station RL-01007 is listed as Impaired for Aquatic Life due to DO and Chlorophyll a levels.
- Duke Power operates the Cedar Creek hydro, and, to a lesser extent, Rocky Creek hydro for peaking energy. These units are operated only when Fishing Creek hydro operates since the Cedar Creek Reservoir has very limited storage
- Currently, Units 2 and 3 have some aeration capability, but have not been evaluated to data.

<u>Findings (Existing Conditions)</u>

- Very short retention times in the channel between Dearborn hydro and Cedar Creek hydro result in the water quality essentially mimicking the water quality released from Dearborn. [**data analysis**]
- The reservoir section from the Catawba bypassed channel to Cedar Creek hydro has a longer retention time as indicated by vertically stratified dissolved oxygen concentrations, pH, and conductivity and with lower nutrient concentrations than found downstream of Dearborn hydro. These conditions are consistent with the development of high algal concentrations in the surface layers and high sediment oxygen demands in the upper portions of Cedar Creek reservoir. [**data analysis**]
- Rocky Creek (River) proportionately dilutes the concentrations of the chemical constituents released from Fishing Creek reservoir. [**data analysis**]
- Any proposed changes in storage and release patterns from Fishing Creek hydro, including supplemental flow through the Great Falls bypassed reach, would be reflected in Cedar Creek reservoir, including, but not limited to an increase in the DO levels flowing into Cedar Creek reservoir from the bypassed reach. [**data analysis**]

Cedar Creek / Rocky Creek Tailrace

<u>Findings (Existing Conditions)</u>

- On the average, during May – November, 13 % of the hourly average dissolved oxygen concentrations released from Cedar Creek hydro are lower than the current state standard of 4 mg/l instantaneous [**data analysis**]
- On the average, during May – November, 37 % of the daily average dissolved oxygen concentrations released from Cedar Creek hydro are lower than the current state standard of 5 mg/l daily average [**data analysis**]
- Actual five year (1997-2000) average nutrient Wylie Releases Compared to Fishing Creek Releases: [**data analysis**]
    - Phosphorus – ? from __ ug/l to __ ug/l
    - Dissolved Organics ? from __ ug/l to __ ug/l
    - Particulate Organics – ? from __ ug/l to __ ug/l.

<u>WATEREE DEVELOPMENT</u>

Lake Wateree

<u>Findings (General Overview)</u>

- Lake Wateree has a moderate retention time. Most of the flow entering Lake Wateree comes from the Cedar Creek hydro.
- Duke Power operates the Wateree hydro for peaking energy, maintenance of target lake levels, and downstream water use.
- Units 1 and 3 have new autoventing runners and provide very good aeration capability. The remaining units have limited potential for turbine venting aeration.
- Stratification is weak to moderate but stable for the most part.
- SCDHEC lists Lake Wateree as impaired due to high total phosphorus, chlorophyll a, and pH. Station CL-089 is Impaired for Aquatic Life due to pH; Station CW-040 is Impaired for Recreation due to Fecal Coliform; Station CW-207, 208 and 209, are Impaired for

Aquatic Life due to pH, Total Phosphorus, Chlorophyll a, Turbidity; Station CW-231 is Impaired for Aquatic Life due to Total Phosphorus, Turbidity; Station RL-02314 is Impaired for Aquatic Life due to pH and Total Phosphorus; Station CW-072 is Impaired for Aquatic Life and Recreation due to DO, pH, and Fecal Coliform; Station CW-019 is Impaired for Aquatic Life due to DO; Station CW-039 is Impaired for Fishing due to Mercury; and Station CW-214 is Impaired for Aquatic Life and Fishing due to DO and Mercury.

Findings (Existing Conditions)

- Wateree Reservoir receives high concentrations of nutrients and organic matter and low concentrations of DO from the Cedar Creek-Rocky Creek Project. Since Fishing Creek, Great Falls, and Cedar Creek Reservoirs have very short retention times with limited internal processing of pollutant loads, the majority of the nutrient loads to Lake Wateree originate upstream of Fishing Creek reservoir. [**data analysis and modeling**]
    - Total phosphorus in the inflows to Wateree is over 3 times greater than the SCDHEC water quality standard and 6 times greater than the TP level in the Wylie releases.
    - Organic matter entering Wateree is almost __ times greater than that discharged from Wylie Reservoir.
    - The nutrients and organic loads are attributed to Municipal and Industrial wastewater discharges as well as nonpoint sources entering the watershed between Wylie and the inflow to Fishing Creek Reservoir.
    - These pollutant loads cause high algae concentrations, producing even more organic matter, and low DO in Wateree Lake.
    - Wateree Lake traps about 50% of the TP entering the reservoir through sedimentation and biological processing.
- DO concentrations throughout much of the reservoir periodically can be less than 5 mg/L. Concentrations of DO less than 4 mg/L periodically can occur at the surface of the lake in some parts of the reservoir. These low DO conditions occur in the reservoir because of high DO demands in the lake that are caused by organic matter in the reservoir that comes from the upstream watershed as well as algae that grow in the lake. [**data analysis and modeling**]
- Algae concentrations in the lake sometimes exceed 50 ugChl*a*/L, which is greater than the SC DHEC standard of 40 ugChl*a*/L. [**data analysis and modeling**]
- BOD_5 values in the river upstream from Fishing Creek reservoir are 2-3 times normal levels (based on USGS and SCDHEC data). When a lake has such high DO demands in the water, it is susceptible to episodes of low DO throughout the water column following inevitable mixing events caused by windy and/or cool weather conditions. [**data analysis and modeling**]

WatereeTailwater

Findings (Existing Conditions)

- On the average, during May – November, __ % of the hourly average dissolved oxygen concentrations released from Wateree hydro are lower than the current state standard of 4 mg/l instantaneous [**data analysis**]
- On the average, during May – November, __ % of the daily average dissolved oxygen concentrations released from Wateree hydro are lower than the current state standard of 5 mg/l daily average [**data analysis**]

- Actual five year (1997-2000) average nutrient Cedar Creek Releases Compared to Wateree Releases: [**data analysis**]
    - Phosphorus – increase from 221 ug/l to 104 ug/l
    - Dissolved Organics – increase, 5.9 mg/l to 5.3 mg/l
    - Particulate Organics – increase from 9.3 mg/l to 4.2 mg/l.
- Temperature and DO are very dynamic in the 4-mile section between the Wateree Dam and downstream of Mickle Lake Island (RM 74.0). This rocky, shoaling section of the Wateree River is dominated by a succession of native attached aquatic plants. A ground water input immediately downstream of Wateree Dam contributes to a lower temperature on the east side of the river. Fluctuating water levels below the dam have sometimes caused fish kills at this location
    - During low flows (leakage and one unit generation), the extensive aquatic plant communities and shoal control DO concentrations, regardless of aeration of the released water [**data analysis and modeling**].
    - During higher generation flows, DO concentrations downstream are reflective of the concentrations released from Wateree hydro. [**data analysis and modeling**]
- Downstream of Mickle Lake Island, the river transitions from a shoal dominated system to that of a sandy bottom.
    - At low flows, the temperatures are dominated by the gradual diel heating and cooling cycles as the water moves downstream. Dissolved oxygen concentrations are indicative of the organics released from Lake Wateree and the diel cycle of planktonic organisms. [**data analysis and modeling**]
    - At higher generation flows, the characteristics of the water released from Wateree hydro are realized further downstream, with temperature and dissolved oxygen changes similar to low flow conditions, but, occurring at a slower rate. [**data analysis and modeling**]

Modeling Scenarios

The following section provides a summary of the CE-QUAL-W2 (reservoir) and RMS (riverine) model scenarios being run for the Project developments (additional scenarios may be added in the future). No modeling is being conducted on the Dearborn/Great Falls and Cedar Creek/Rocky Creek Developments

Bridgewater Development

- ***Provide Aerated Releases from Bridgewater Hydro to current state standard of 5 mg/l dissolved oxygen***
    - Dissolved oxygen improvement in the first 10 miles below the dam, with a diminishing increment with distance downstream from the dam. Beyond 10 miles downstream, no aeration increment would be observable (What does it do for 5mg/l and 4 mg/l-are these met or not and how far downstream).
- ***Provide Aerated Releases from Bridgewater Hydro to current state standard of 6 mg/l dissolved oxygen***
- ***Provide Supplemental flow to the Catawba Bypassed Reach from the Catawba Dam to meet Aquatic Use Requirements – Impact of temperature and dissolved oxygen in Lake James***
    - To achieve the same lake level, higher supplemental flow to the bypassed reach would reduce Bridgewater release volume proportionately.

- The Linville forebay cold water would be preserved longer with the lower Bridgewater release.
- Deep water withdrawal from forebay of the Catawba arm would reduce dissolved oxygen concentrations in the upper portion of Lake James.
- Surface water withdrawal from forebay of the Catawba arm would slightly decrease dissolved oxygen concentrations in the upper portion of Lake James

- ***Provide Supplemental flow to the Catawba Bypassed Reach from the Catawba Dam and Bridgewater Hydro to meet Aquatic Use Requirements – Impact of Temperature on Downstream Reaches (assumes supplemental oxygenated water that meets state standards))* Note: these conditions are yet to be determined and require the results of the forthcoming IFIM studies***
    - Supplemental flow from deeper depths at the Catawba Dam in Lake James
        - Catawba bypass reach flows would maintain cooler water in the downstream sections of the Bridgewater tailwater (trout water).
        - These cooler temperatures in the bypassed reach may not be preferred mussel temperatures
    - Supplemental flow from shallow depths at the Catawba Dam in Lake James
        - Catawba bypass reach flows would tend to warm the water in the downstream sections of the Bridgewater tailwater. Higher Catawba bypass flows (100-200 cfs) caused warming of the trout fishery from XX temp. to XX temp.
        - These warmer temperatures in the bypassed reach would be preferred mussel habitat
    - Combinations of Bridgewater and Catawba bypassed reach minimum flows could be provided that would meet thermal objectives for the Catawba bypassed reach (mussel habitat) as well as the Bridgewater tailwater (trout habitat).
        - At lower Catawba bypass flows (25-50 cfs), the water could be withdrawn at a temperature more optimal for mussels, and, combined with additional minimum flow from Bridgewater hydro, preferred trout habitat could be maintained in the downstream section of the Bridgewater tailwater.
        - In the section of the Catawba bypassed reach upstream of the confluence with Muddy Creek, water quality in the Catawba bypassed reach is expected to be characteristic of the lake water used to supplement the flows to the bypassed reach
        - In the section of the Catawba bypassed reach downstream of the confluence with Muddy Creek, water quality in the Catawba bypassed reach is expected to be characteristic of the mixed proportional flow of the lake water used to supplement the flows and of Muddy Creek
        - Any supplemental flow releases in the Catawba Bypassed Reach will require a balance between the various stakeholder use scenarios

Rhodhiss Development

- ***Reduce Nutrient Input to Lake Rhodhiss (will be evaluated)***
    - Preliminary evaluation suggests that reduced nutrient loading to the lake may improve water quality in the reservoir and its releases and potentially in downstream developments

- ***Continued Sedimentation in Lake Rhodhiss – Impact on Water Quality (will be evaluated)***
    - There currently is significant loss of reservoir volume in Lake Rhodhiss due to sedimentation. Water quality parameters will be evaluated in association with the projected sedimentation rates within the reservoir and associated loss of reservoir volume, as well as the effects to downstream projects (check with CHEOPS model).
- ***CHEOPS Flow Scenarios-Impact on Water Quality***
- ***Provide Aerated Releases from Rhodhiss Hydro to current state standard of 5 mg/l dissolved oxygen (less than 1 to 5 mg/l) (to be evaluated)***
    - Evaluate improvement of dissolved oxygen in headwaters of Lake Hickory
    - The effect of low DO in the discharges from Rhodhiss on Hickory is that the DO is less than 5 mg/L for about 8 km.

<u>Oxford Development</u>

- ***Reduce Nutrient Input to Lake Hickory (currently being evaluated)***
    - Phosphorus reduction scenarios were considered by reducing inputs from Rhodhiss and waste treatment facilities discharging directly into the lake.
    - Preliminary results of these model predictions showed that algae levels would be reduced significantly but that DO conditions would be improved much less, both in the lake as well as in the releases from Hickory

- ***Provide Aerated Releases from Oxford Hydro to current state standard of 5 mg/l dissolved oxygen (less than 1 to 5 mg/l), with and without vegetation in the river (grass carp stocked in 2005 to control aquatic weeds)***
    - With vegetation, aeration to state standards at Oxford Dam would result in almost +1 mg/L improvement in minimum DO three miles downstream. Thus, aquatic vegetation will tend to dampen the apparent benefit of Oxford aeration for water flowing into Lookout Shoals Reservoir.
    - Without vegetation, aeration to state standards at Oxford Dam would result in +2 mg/L improvement in minimum DO three miles downstream (at the Lookout Shoals inflow location).

<u>Lookout Shoals Development</u>

- ***Provide Aerated Releases from Oxford Hydro to current state standard of 5 mg/l dissolved oxygen (less than 1 to 5 mg/l), with and without vegetation in the river (grass carp stocked in 2005 to control aquatic weeds) to test the effects of aerating at Oxford to determine the effects at discharge from Lookout Shoals***
    - Of the 3 mg/l increase in dissolved oxygen added to the Oxford release, about 0.5 mg/L improvement would be observed in Lookout Shoals release. This result is essentially the same whether or not weeds are present in the upstream Oxford tailwater model.
    - What is unknown, is the impact of the grass carp on the removal of aquatic weeds in the Lookout Shoals reservoir

- ***Continued Sedimentation in Lookout Shoals Reservoir – Impact on Water Quality (will be evaluated)***
    - There currently is significant loss of reservoir volume in Lookout Shoals due to sedimentation. Water quality parameters will be evaluated in association with the

projected sedimentation rates within the reservoir and associated loss of reservoir volume, as well as the effects to downstream projects (check with CHEOPS model).

- ***Since Lake Norman is the main storage reservoir on the Catawba River, any proposed changes in storage and release patterns from upstream or downstream projects may potentially alter the water quality (to be evaluated)***.
  - Evaluate the dissolved oxygen concentrations downstream of Lookout Shoals (especially during the critical summer period) with respect to potential changes in Lake Norman lake levels.

Cowans Ford Development

- ***Since Lake Norman is the main storage reservoir on the Catawba River, any proposed changes in storage and release patterns from upstream or downstream projects may potentially alter the water quality (to be evaluated)***.
  - Aquatic Habitat Evaluation for Striped Bass
  - Thermal regimes for steam station cooling water

Mountain Island Development

- ***Impact of Mecklenburg County Storm Water and Waste Treatment Plant initiatives on the water quality of Charlotte's municipal water supply.***
  - Storm water inflows to be evaluated in association to affecting Charlotte water supply intake
  - Water quality improvements in McDowell Creek following phosphorus reduction at the WWTP – Mecklenburg County-Buetow to provide additional modeling scenarios associated with nutrient improvements or proposed improvements.

- ***Provide Aerated Releases from Mountain Island Hydro to current state standard of 5 mg/l dissolved oxygen (less than 3 to 5 mg/l)to test effects of aerating on Lake Wylie (to be evaluated)***
  - Evaluate improvement of dissolved oxygen in headwaters of Lake Wylie

- ***Provide Flows to Mountain Island bypassed reach to enhance aquatic habitat in the bypassed reach (to be evaluated)***
  - Evaluate improvement of dissolved oxygen in headwaters of Lake Wylie

Wylie Development

- ***Reduce Nutrient Input to Lake Wylie (currently being evaluated)***
  - Phosphorus reduction scenarios were considered by reducing inputs from South Fork River and Crowders Creek..
  - Preliminary results of these model predictions showed that algae levels would be reduced significantly but that DO conditions would be improved much less, both in the lake as well as in the releases from Wylie.

- ***Provide Aerated Releases from Wylie Hydro to current state standard of 5 mg/l dissolved oxygen (less than 1 to 5 mg/l). (to be evaluated)***

- ***Provide Supplemental flow to meet Aquatic Use Requirements (to be evaluated)***

<u>Fishing Creek Development</u>

- ***Reduce Nutrient Input to SCDHEC standards in Fishing Creek Reservoir (will be evaluated)***
  - Direct impact on Fishing Creek Reservoir
  - Impact on downstream projects

- ***Continued Sedimentation in Fishing Creek – Impact on Water Quality (will be evaluated)***
  - There currently is significant loss of reservoir volume in Fishing Creek Reservoir due to sedimentation. Water quality parameters will be evaluated in association with the projected sedimentation rates within the reservoir and associated loss of reservoir volume, as well as the effects to downstream projects (check with CHEOPS model).

- ***Provide Supplemental flow to the Great Falls bypassed reach to meet Aquatic Use Requirements (to be evaluated)***
  - Evaluate change in operation on the water quality of Fishing Creek Reservoir (check with CHEOPS).

<u>Wateree Development</u>

- ***Reduce Nutrient Input to SCDHEC standards in Fishing Creek Reservoir (will be evaluated)***
  - Direct impact on Wateree Reservoir

- ***Continued Sedimentation in Fishing Creek – Impact on Water Quality (will be evaluated)***
  - There currently is significant loss of reservoir volume in Fishing Creek Reservoir due to sedimentation. Water quality parameters will be evaluated in association with the projected sedimentation rates within the reservoir and associated loss of reservoir volume, as well as the effects to downstream projects (check with CHEOPS model).
- ***Provide Aerated Releases from Wylie Hydro to current state standard of 5 mg/l dissolved oxygen (less than 1 to 5 mg/l). (to be evaluated) (Does this belong under Wylie?)***

- ***Provide Supplemental flow to meet Aquatic Use Requirements (to be evaluated)***

- ***Provide Supplemental flows to support diadromous fish requirements. (to be evaluated)***

- ***Impact of Wateree generation on floodplain inundation. (to be evaluated)***

Other Findings Opinions

To be provided

4.0 Assessment of Resource Improvement Options

The section includes a list of resource improvement options that address the preceding problems/causes as directly as possible. These resource improvement options represent a menu of initiatives for consideration by the State Relicensing Teams and the Regional Advisory Groups as they negotiate the Agree-in-Principle (AIP). It is not necessary or expected for all of these initiatives to be included in the AIP. Also, other initiatives in combination with or in lieu of the options listed in this report may be included in the AIP.

Based on preliminary findings, enhancements are needed to meet state water quality standards for DO in all hydro tailrace releases. In association with Table 4-1, the following water quality enhancement measures (turbine aeration for dissolved oxygen enhancement) are defined and proposed as potential water quality improvement options:

- **Stay Vane:** An air flow enhancing measure with fixed metal vanes fitted to the inner periphery of the scroll case that guide the water from the scroll case to the turbine runner.
- **Vacuum Breaker:** An air flow enhancing device which automatically vents a water line to the atmosphere when subjected to a partial vacuum**.**
- **Auto Venting Runner:** An air flow enhancing measure that increases DO concentrations in releases by aspirating and mixing air with the water passing through the turbine runner.
- **Hub Venting**: An air flow enhancing measure that draws air into the turbines and mixes it with the water.
- **Forebay oxygen injection**: Oxygen is mechanically injected in a reservoir immediately upstream of the hydropower intakes so that most of the injection is contained within the withdrawal and released downstream. The system typically consists of an oxygen tank that connects to a perforated hose that is suspended off the bottom. Oxygen is pumped into the hose and into the water column.

The items listed below are resource options recommended by the Aquatics RC in relation to water quality measures.

- Bypasses may need additional flow to meet aquatic use (narrative) Section 401 standards.
- Flow and temperature regime changes in bypassed reaches below Lake James must be compatible with both mussel and trout management objectives.
- Reduce nutrient contributions from point and non-point sources.
- Establish an approved monitoring plan providing representative results under various operation conditions.
- In coordination with Aquatics RC, provide higher and more stable base flow releases in bypassed and regulated river reaches.
- Support supplemental nutrient and sediment reduction initiatives.
- Continue long-term coordination with state and local governments on water quality management efforts.
- Modify hydro station equipment and/or operations to meet state DO standards (table of options follows).

Table 4-1. Water Quality Resource Improvement Options

Hydro Development	Existing Powerhouse Capacity*	Potential Water Quality Improvement Options**

Hydro Development	Existing Powerhouse Capacity*	Potential Water Quality Improvement Options**
Bridgewater	Vacuum Breaker aeration capability on two units	**Vacuum Breaker Enhancement** ➢ Capital - $200,000 **Forebay O2 Injection** ➢ Capital - $1,000,000 ➢ O&M (yearly) = $71,000 **Continuous DO Monitor** ➢ Capital - $20,000 ➢ O&M (yearly) = $20,000
Rhodhiss	Stay Vane venting modification on Unit 2	**Stay Vane Enhancement** ➢ Cap - $150,000 **Forebay O2 Injection** ➢ Capital - $1,200,000 ➢ O&M (yearly) = $250,000 **Continuous DO Monitor** ➢ Capital - $20,000 ➢ O&M (yearly) = $20,000
Oxford	Hub Venting capability on two units	**Forebay O2 Injection** ➢ Capital - $880,000 ➢ O&M (yearly) = $95,000 **Continuous DO Monitor** ➢ Capital - $20,000 ➢ O&M (yearly) = $20,000

Hydro Development	Existing Powerhouse Capacity*	Potential Water Quality Improvement Options**
Lookout Shoals	Vacuum Breaker Aeration capability on 3 large units	**Vacuum Breaker Enhancement** ➢ Cap = $225,000 **Forebay O2 Injection** ➢ Capital - $695,000 ➢ O/M (yearly) = $36,000 **Continuous DO Monitor** ➢ Capital - $20,000 ➢ O&M (yearly) = $20,000
Cowans Ford		**Forced Air Injection** ➢ Capital = $500,000 **Forebay O2 Injection (??)** **Continuous DO Monitor** ➢ Capital - $20,000 ➢ O&M (yearly) = $20,000
Mountain Island	Vacuum Breaker aeration capability and Stay Vane venting modifications on Units 2, 3, and 4	**Stay Vane Enhancement and Baffles** ➢ Capital - $200,000 **Forebay O2 Injection (??)** **Continuous DO Monitor** ➢ Capital - $20,000 ➢ O&M (yearly) = $20,000

Hydro Development	Existing Powerhouse Capacity*	Potential Water Quality Improvement Options**
Wylie	Hub Venting capability on Units 2 and 3	**Vacuum Breaker Enhancement** ➢ Capital = $75,000 **Auto Venting Runner** ➢ Capital = $1,000,000 **Forebay O2 Injection** ➢ Capital - $880,000 ➢ O&M (yearly) = $193,000 **Continuous DO Monitor** ➢ **Capital** - $20,000 ➢ O&M (yearly) = $20,000
Fishing Creek	Hub Venting capability on Unit 3 and Stay Vane venting modification on Units 1 and 2	**Stay Vane Enhancement** ➢ Capital = $220,000 **Forebay O2 Injection** ➢ Capital- $695,000 ➢ O&M (yearly) = $152,000 **Continuous DO Monitor** ➢ Capital - $20,000 ➢ O&M (yearly) = $20,000
Dearborn	Vacuum Breaker aeration capability on all three units	**Stay Vane Enhancement** ➢ Capital = $225,000 **Forebay O2 Injection** ➢ Capital - $1,200,000 ➢ O&M (yearly) = $71,000 **Continuous DO Monitor** ➢ **Capital** - $20,000 ➢ O&M (yearly) = $20,000
Cedar Creek	Hub Venting capability on Units 2 and 3	**Forebay O2 Injection (??)** **Continuous DO Monitor** ➢ Capital - $20,000 ➢ O&M (yearly) = $20,000

Hydro Development	Existing Powerhouse Capacity*	Potential Water Quality Improvement Options**
Wateree	Auto venting runners for Units 1 and 3 and Hub Venting capability on Unit 2	**Vacuum Breaker Enhancement** ➢ Capital = $150,000 **Forebay O2 Injection** ➢ Capital - $1,200,000 ➢ O&M (yearly) = $272,000 **Continuous DO Monitor** ➢ Capital - $20,000 ➢ O&M (yearly) = $20,000
All		**Measures and partnerships for point-source and non-point nutrient reductions**
Total		**Capital: $10,915,000** **Annual O&M: $1,360,000**

Note: The cost estimates do not include lost generation due to air injection for turbine venting and/or miscellaneous follow-up studies. The additional aeration at Fishing Creek was used to assess future needs at Dearborn and Cedar Creek. All aeration costs were based upon calculated daily oxygen deficits. DO monitor costs were based upon current USGS values.

* To quantify the effectiveness of the recent or current modifications on each of the above mentioned hydro developments, additional testing may be required especially under new operating conditions. The effectiveness of these current modifications has a direct bearing on scope (e.g., type and number of applied measures) of future relicensing water quality improvement options.

** Continuous DO monitoring will be a Section 401 Water Quality Certification requirement for both North and South Carolina reservoirs (i.e., downstream of the hydro-tailwater/tailrace). A DO Monitoring Plan will be developed, including potential locations for continuous DO monitors, in consultation with the Water Quality RC.

4.4 Other Resource Opinions

To be determined